Technological Change in Agriculture in Southeastern Mexico: Implications for Land Use, Deforestation, and Climate Change Policy

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RESEARCH OBJECTIVES

This research seeks to:

- Develop an understanding of the diffusion of new agricultural technologies and how this technological change affects land use choices in southeastern Mexico.
- Shed light on the socioeconomic processes (almost entirely agricultural expansion) that lead to deforestation in the region.
- Contribute to the debate on the potential for accurate estimation of the greenhouse gas benefits of land-use change and forestry projects with implications for the best role for such projects in the Clean Development Mechanism included in the Kyoto Protocol.

PRESENTATION OBJECTIVES

- Last summer at PNNL my presentation focused on policy-oriented objectives.
  - For context, I explained flexibility mechanisms (e.g. carbon credit trading) under the Kyoto Protocol and the debate about the best role for land-use change and forestry projects;
  - I discussed using modeling results for forecasting future scenarios and using scenarios to estimate the greenhouse gas benefits of projects.
- Today I focus on efforts to understand the process of technological change in the study area and implications of this for land use.

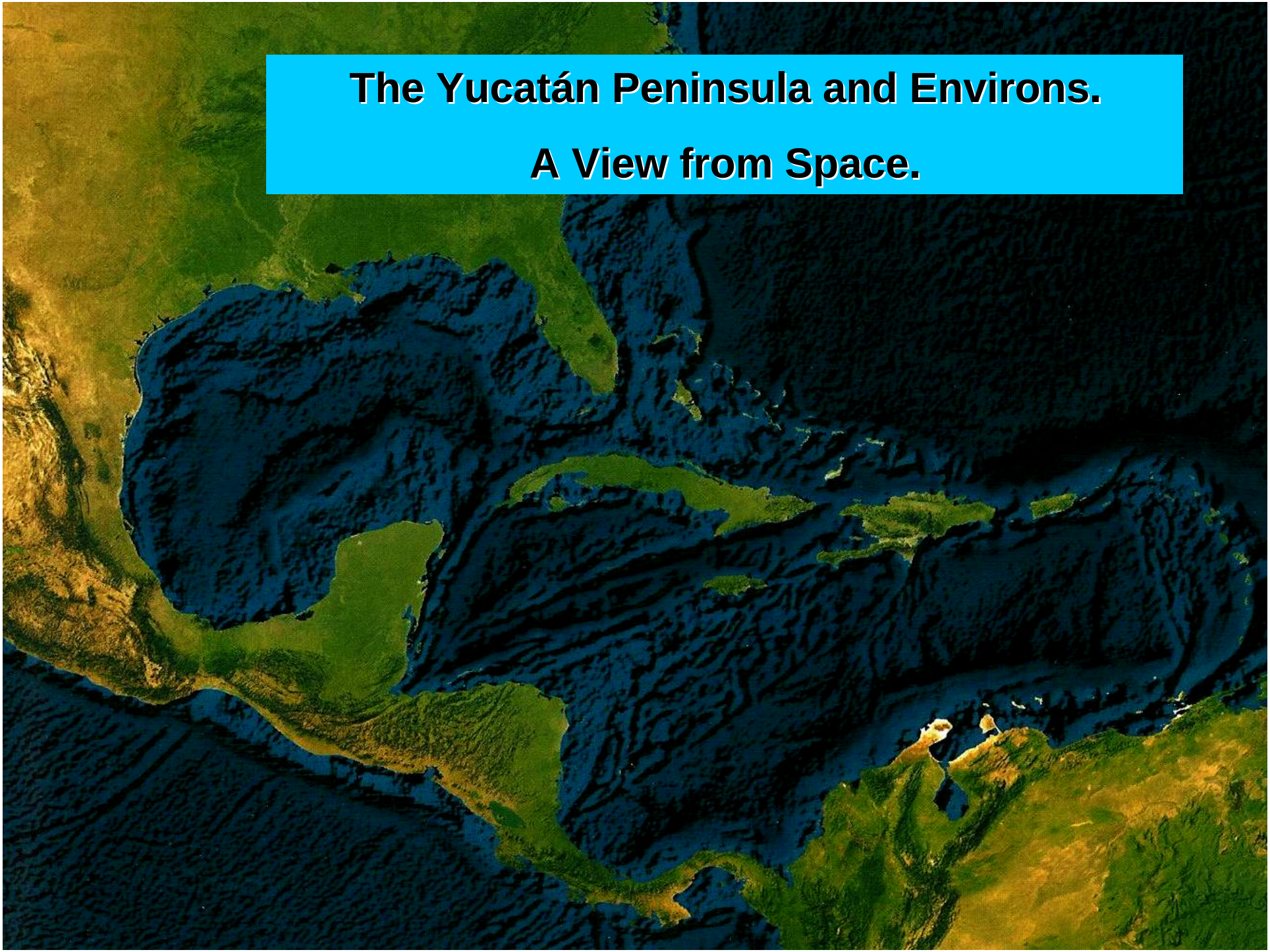
Outline: Remainder of Presentation

- **Context:** The Problem and Its Significance.

2. **Research Methods:**
    - Theoretical Modeling.
    - Econometric Modeling.
    - Hypotheses.
    - Survey Design and Implementation.
3. **Conclusion:**
    - Current Work.
    - Schedule for Finishing.
    - Future Work.

CONTEXT: Some Practicalities

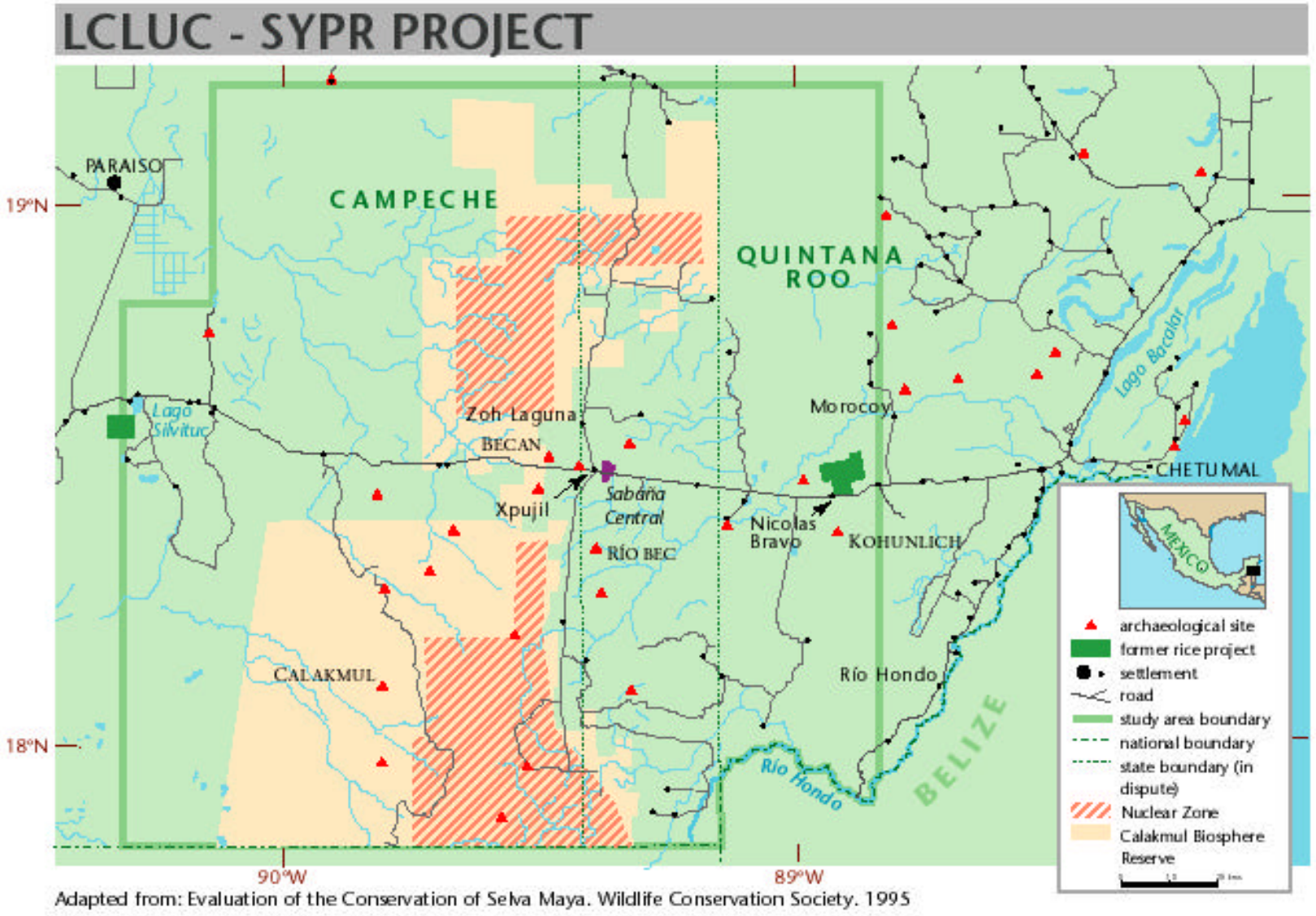
- Partnership with a NASA Land-Use, Land-Cover Change Project that is studying the area.
- Previous fieldwork in April 2001, January 2002.
- Extended fieldwork for the purposes of household surveys to begin November 2002.
- Now some geographic orientation.


The Yucatán Peninsula and Environs.
A View from Space.

The Yucatán Peninsula.

Political Map.

Southern Yucatán Peninsular Region
As Defined By NASA Project



Adapted from: Evaluation of the Conservation of Selva Maya. Wildlife Conservation Society. 1995

Thumbnail Sketch of the Problem and Its Significance

- Farmers in Mexico's Southern Yucatán Peninsula Region (SYPR) are adopting a new cash crop – jalapeño chili peppers.
- New production methods – agrochemicals and mechanized soil preparation – are being used to grow the crop.
- Deforestation rates are increasing because farmers are devoting a larger fraction of their land holdings to agriculture.
- SYPR contains Mexico's most extensive undisturbed forestland.

Profiling the Agricultural Sector

- Key actors are household farmers, who practice shifting cultivation (also called slash and burn or, in local terms, swidden production).
- Increasingly farmers pursue profit in addition to subsistence objectives. Prior to chili, no pure cash crops.
- There are emerging agronomic problems (pests, weeds, the spread of invasive species) due to chemical use for chili cultivation and shorter fallow periods.

Introduction and Diffusion of Chili

- Introduced by three farmer migrating from Chiapas to the SYPR in the mid-1970s.
- This is primarily a story of diffusion (as opposed to innovation, another important aspect of technological change).
- 54% of households grew chili in a 1998-1999 survey.
- 85% of households grew chili in a separate 1999-2000 survey of the “Zonas Chileras.”

The Market for Chili from the SYPR

- SYPR product is exported to Mexico City. (Note this implies the price of chilies is exogenous.)
- The region plays a minor role in national chili production. Demand is stronger when there are problems (due to weather, pests) in traditional chili growing strongholds.
- Due to fluctuations in demand, there is substantial price risk. The price of chili is highly variable.
- Note: An implications of national demand for chili is that the size of the local population will not serve to limit the growth of chili cultivation, though relatively poor soils and an inability to irrigate might.

The Mechanization Factor

- Though all farmers use chemicals to grow chili, only 30% are mechanized.
- Household wealth and liquidity constraints seems to be the main reason we do not see greater diffusion of mechanization. All farmers profess a desire to mechanize.
- Productivity differential: Mechanized chili farmers produce about 50% more per hectare than swidden farmers.

Land Use and Productivity of Chili Farmers in Keys (2002) survey

	All Farmers (n=133) *	Mechanized Farmers (n=46)	Swidden Farmers (n=87)
Land Use: Hectares of Chili Cultivated			
mean	**1.30**	**1.73**	**1.17**
sd	0.73	0.79	0.60
median	1.00	1.50	1.00
Productivity: Kg of Chile / Hectare			
mean	**4,900**	**6,300**	**4,200**
sd	4,200	5,500	3,000
median	3,800	5,000	3,600

*from the population of chili farmers in the Zonas Chileras surveyed in 1999-2000.

RESEARCH METHODS

- Preface.
- A Theoretical Model.
- Econometric Modeling.
- Survey Design and Implementation.

Preface to Methods Discussion

- Introduction to economic models.
  - Note physics envy.
  - Model types: (1) descriptive (positive) vs. normative;
    (2) individual vs. aggregate.
  - Central role for the mathematical technique of constrained optimization (Lagrange multiplier method).
- Defining econometrics – sorry, no single accepted definition. Key is managing problems that follow from inability to conduct controlled laboratory experiments.
- There exist differing opinions about the importance and role of theory in empirical social science research.

The Theoretical Model: Preliminaries

- The model developed here seeks to explain farmers' allocation of land among different crops in light of the price risk (variability over time) and differences among attitudes towards risk among households.
- Here, consider three crop options.
  - m: maize (the traditional crop)
  - c1: un-mechanized chili
  - c2: mechanized chili
- Am going to speed through technical details, but want to give the flavor of such a model.

The Theoretical Model (Continued)

- Model is known as portfolio model with risk, and is related to mean-variance models used in finance.
- The model incorporates the idea that people prefer certainty, or put differently that variability is costly (at least when it comes to an income flow; after all, variety is the spice of life).
- Assume that stochastic profits are normally distributed and can be characterized by their mean and variance.

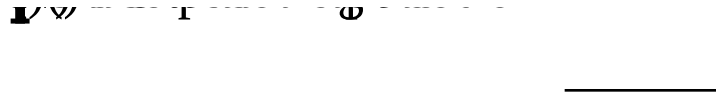
Profits: Definitions and Assumptions

Income:
Definition, Expectations and Variances

Decision Framework

- Assume that utility is a separable function of income and non-random leisure.
- Assume that expected utility from stochastic income takes a mean-variance form.
- So expected utility in a given time period is

- Assuming a forward looking agent, define the present value of EU



The Constrained Optimization Problem

Lagrangian and First-Order Conditions (or, Convincing You This is Scientific)

Reduced-Form Equations

- First-order conditions are necessary conditions, and so imply the following reduced-form equations for land area devoted to each crop.

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- These provide the link between theory and econometric work.

Econometrics

- Estimate a panel data model by parameterizing reduced form equation.
- Reason to suspect fixed effects based on village membership. Test fixed vs. random effects (Hausman test). A fixed effects model:

Econometrics (continued)

- Will want to consider taking into account selection effects (entrepreneurial spirit).
- Do this via a two-stage Heckman procedure. Bring in a type of network effect. Suppose greater aggregate adoption reduces the fixed cost of adoption. Include this in the first stage probit on adopt chilies or not, but not in the land use equation.
- Stack the three equations and run as a system of Seemingly Unrelated Regression equations (accounts for cross equation correlation in error terms).

Hypotheses:
Some Key (A Priori) Hypotheses

- Will find risk aversion among household farmers in the study area, e.g. measures of absolute and relative risk aversion will be non-zero.
- The measure of absolute risk aversion will play a significant role in determining land use.
- The budget constraint will bind (the multiplier will be significantly different from zero), but the land constraint will not bind (the multiplier will not be significantly different from zero).

Survey Issue: Sampling Strategy

- Employ a stratified, two-stage cluster sampling strategy.
- Ejidos (villages) as the first-stage unit and households as the second-stage unit.
- Stratify ejidos according to
  - the north-south rainfall gradient
  - access to Highway 186
  - older, land rich vs. newer, land poor.

Survey Issue: Data Collection.

Categories of variables targeted for collection from each household:

- Land Use
- Profits (Revenue and Costs)
- Income, Credit, and Assets
- Demographics
- Community

CONCLUSION: Current Work

Issues I continue to work on:

- How to address another area of technological change – changes in shifting cultivation patterns over time?
- Development of directly testable theoretical results (e.g. strengthen the link between theory and econometrics).
- How to better link the individual model to the larger (aggregate) economic landscape?

Schedule for Finishing Dissertation

- Draft survey text by September 1, 2002.
- Begin extended fieldwork November 1, 2002. Contact village leaders. Pretest survey.
- Begin survey implementation January 2003.
- Finish survey work September 2003.
- Finish dissertation March 2004.

Future Work: Policy Dimensions

- Note that payment for climate change mitigation value of forests may be one of few win-win policy options in tropical frontier regions.
- Use modeling results as basis for estimation of greenhouse gas (GHG) benefits due to the Nature Conservancy's Calakmul Biosphere Project.
- Compare results with those Winrock International research team, which is assessing the Calakmul Project with four different methods.
- Shed light on the controversy over the potential for accurate GHG benefit estimation for land-use change and forestry projects and thereby on the debate over their inclusion in project allowed under the CDM.

Acknowledgement

This work would not be possible without funding from the Global Change Education Program.

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